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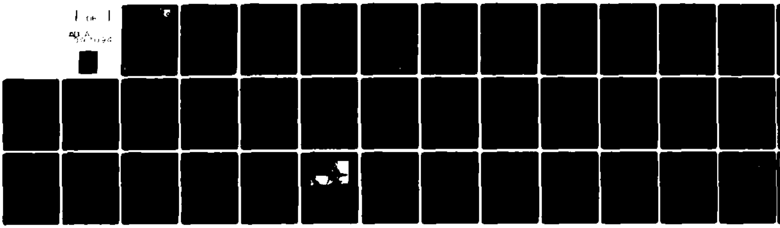

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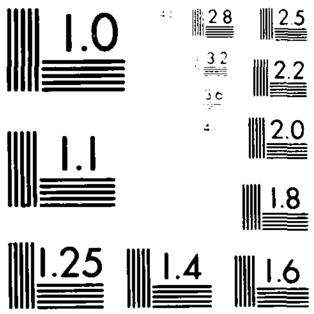

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AFWAL-TR-80-3146
Part I

TRANSONIC AND LOW SUPERSONIC WIND-TUNNEL TESTS ON A WING WITH INBOARD CONTROL SURFACE

Part I. General Description

National Aerospace Laboratory
The Netherlands

DECEMBER 1980

TECHNICAL REPORT AFWAL-TR-80-3146, Part I.
Final Report for the period January 1979 through July 1980

FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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⑲ TR-80-3146-PT-1

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REPORT DOCUMENTATION PAGE

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BEFORE COMPLETING FORM

1. REPORT NUMBER ⑱ AFWAL-TR-80-3146, Part I.	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER AD-A097 094
4. TITLE (and Subtitle) ⑥ TRANSONIC AND LOW SUPERSONIC WIND-TUNNEL TESTS ON A WING WITH INBOARD CONTROL SURFACE. Part I. General Description.	5. TYPE OF REPORT & PERIOD COVERED ⑨ Final Rep[redacted]t. Jan[redacted]79-Dec[redacted]80
	6. PERFORMING ORG. REPORT NUMBER NLR TR 80070L Part I
7. AUTHOR(s) ⑩ A. J. Persoon, R. Roos[redacted] P. Schippers	8. CONTRACT OR GRANT NUMBER(s) ⑮ AFOSR-79-0023
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Aerospace Laboratory (NLR) Amsterdam, the Netherlands ⑰ 02	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE: 61101F, Project ⑯ 2401 Task: 240102 Work Unit: 24010232
11. CONTROLLING OFFICE NAME AND ADDRESS Flight Dynamics Laboratory (AFWAL/FIBRC) Air Force Wright Aeronautical Laboratories (AFSC) WPAFB, OH 45433	12. REPORT DATE ⑪ Dec[redacted] 1980
	13. NUMBER OF PAGES 28 ⑫ 39
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ⑭ NLR-TR-80070-L-PT-1	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Transonic	Supersonic
Unsteady Aerodynamics	Experiments
Control Surface	Pressure Data

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A wind-tunnel investigation was carried out on a modified half-model of the F-5 wing with an oscillating in-board control surface. Detailed steady and unsteady pressure distributions were measured over the wing and over the control surface. Sectional as well as total coefficients for the wing and the control surface were obtained by integration of the measured pressure distributions. The tests covered the Mach number range between Ma = 0.6 and 1.25 with frequencies of the control surface of 20 and 40 Hz, which corresponds to a maximum reduced frequency of 0.4 at Ma = 0.6 and 0.215. (Continued on reverse)

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This report (Part I) describes the general set-up of the experiments, while the test results in tabulated form are given in Part II.

FOREWORD

This report was prepared by the National Aerospace Laboratory (NLR) of Amsterdam, the Netherlands. The sponsor was the Flight Dynamics Laboratory (AFWAL/FIBR) of Wright-Patterson Air Force Base, Ohio. The AFOSR Grant 79-0023, "Transonic Wind Tunnel Measurements on a Wing with Oscillating Flaperon", was administered by Captain D. Wilkins of the Air Force Office of Scientific Research (AFOSR/PKN) of Bolling Air Force Base, Washington D.C. The work was performed in support of Project 2401, "Structures and Dynamics", and Task 240102, "Design and Analysis Methods for Aerospace Vehicle Structures".

The report consists of two parts. Part I contains the general description of the model and the test program. Part II presents the test data for the wing with trailing edge control surface in tabulated form. Part II will be available upon request from AFWAL/FIBRC.

The principal investigators were A. J. Persoon, R. Roos, and P. Schippers of NLR. The grant was monitored by L. J. Huttsell and Dr. J. J. Olsen of AFWAL. The assistance of Major R. Powell and Major G. Zielsdorff of the European Office of Aerospace Research Development (EOARD) is appreciated.

The National Aerospace Laboratory expresses its gratitude to the Royal Netherlands Air Force (RNLAF) for their permission to use the modified F-5 wing for this investigation.

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LIST OF SYMBOLS

ALPHA	incidence	(degrees)
AMPL	amplitude of control surface oscillation in section of accelerometer no.1	(degrees)
ARG	argument of unsteady quantity	(degrees)
C	chord	(m)
$\bar{C}$	mean geometric chord; $\bar{C} = 0.4103$	(m)
CM	pitching moment coefficient	
CMI	unsteady pitching moment coefficient	
CMIIM	imaginary part of unsteady pitching moment coefficient	
CMIRE	real part of unsteady pitching moment coefficient	
CN	hinge moment coefficient	
CNI	unsteady hinge moment coefficient	
CNIIM	imaginary part of unsteady hinge moment coefficient	
CNIRE	real part of unsteady hinge moment coefficient	
CP	pressure coefficient	
CPI	unsteady pressure coefficient	
CPIIM	imaginary part of unsteady pressure coefficient	
CPIRE	real part of unsteady pressure coefficient	
CR	control surface normal force coefficient	
CRI	unsteady control surface normal force coefficient	
CRIIM	imaginary part of unsteady control surface normal force coefficient	
CRIRE	real part of unsteady control surface normal force coefficient	
CZ	normal force coefficient	
CZI	unsteady normal force coefficient	
CZIIM	imaginary part of unsteady normal force coefficient	
CZIRE	real part of unsteady normal force coefficient	
DELTA	mean flap deflection	(degrees)
F	frequency of oscillation = FREQ.	(Hz)
i	$\sqrt{-1}$	

LIST OF SYMBOLS (concluded)

K	reduced frequency; $K = \dfrac{2\pi \, . \, F. \, Cr}{2.V}$	
M	pitching moment	(Nm)
Ma	Mach number	
MI	unsteady pitching moment	(Nm)
MLOC	local Mach number	
MOD	modulus of unsteady quantity	
N	hinge moment	(Nm)
NI	unsteady hinge moment	(Nm)
P	free stream static pressure	(Pa)
P_o	stagnation pressure	(Pa)
PI	unsteady pressure	(Pa)
P_{loc}	local pressure	(Pa)
PU	unsteady pressure in scanivalve	(Pa)
Q	dynamic pressure	(Pa)
$R_{L.E.}$	nose radius of airfoil	(m)
R	control surface normal force	(N)
RE	Reynoldsnumber $\ast$ 10^{-6}, based on $\bar{C}$	
RI	control surface unsteady normal force	(N)
RUN	test point identification number	
S	semi-span ; S = 0.648	(m)
t	time	(s)
V	free-stream velocity	(m/s)
x	co-ordinate in free-stream direction	(m)
y	co-ordinate in spanwise direction	(m)
z	co-ordinate normal to free-stream and spanwise direction	(m)
Z	normal force	(N)
ZI	unsteady normal force	(N)
α	magnitude of pressure tube transfer function	
δ	flap deflection (positive downwards)	(rad.)
Δ	difference of two quantities	
φ	phase of pressure tube transfer function	(rad.)
ω	angular velocity; $\omega = 2\pi . F$	(rad./s)

SUBSCRIPTS

control	referring	to	control surface
l	"	"	lower surface
r	"	"	root of the wing
t	"	"	tip of the wing
u	"	"	upper surface
wing	"	"	wing
δ_o	"	"	mean flap deflection
$\Delta \delta$	"	"	difference from two flap deflections

1 INTRODUCTION

In January 1980 wind-tunnel tests were performed on a modified half-model of the F-5 wing with oscillating inboard control surface. The aim of these experiments was to determine unsteady airloads on a representative fighter-type wing in the transonic and low supersonic speed regimes. Such data are necessary to support future developments of calculation methods.

The present report, Part I, describes the test set-up and test techniques and gives a survey of the test program. Part II contains the test results in tabulated form.

2 MODEL AND TEST SET-UP

2.1 General description

The model investigated consisted of a wing equipped with an inboard control surface. The wing was the slightly modified half-model of the outer part of the F-5 wing (scale 1:4.5) used in earlier aeroelastic investigations (References 1 and 2).

In streamwise direction the wing possesses a modified NACA 65-A-004.8 airfoil, characterized by a droopnose, which extends from the leading edge towards the point of maximum thickness at 40 per cent of the chord. Further aft the profile is symmetrical. The line of symmetry of this rear part is chosen as a reference for the incidence. Details of the planform and the airfoil are given in Figure 1.

The model was supported at the side-wall of the test-section (Figure 2). Oscillations of the control surface about the hinge axis could be generated by means of a hydraulic actuator. This hydraulic actuator is equipped with a displacement transducer (no. 10), which controls the position of the piston rod. An additional displacement transducer (no. 9) was mounted on a lever as close as possible to the control surface root and just outside the testsection of the wind tunnel. With transducers nos. 9 and 10 the amplitude of the control surface oscillation as well as the mean steady deflection were monitored. Further details on the hydraulic test rig can be found in Reference 3.

The motions of the control surface and also any resulting motions of the wing were monitored by eight built-in accelerometers (Figure 3). The wing model, made of dural, was provided with 188 pressure orifices and connecting tubes. The pressure orifices were located on the upper and lower surface, distributed over eight spanwise sections on the wing and four on the control surface (Figure 3). From the earlier test (Reference 1), closer spacing of the measuring sections at the tip makes it possible to study tip effects in more detail. In addition twelve miniature pressure transducers were built in the wing and control surface close to the pressure points of section 2 on the upper surface. These transducers are used to provide data for the determination of the transfer function of the tubes during the test.

No use was made of transition strips.

2.2 Wind tunnel

The tests were performed in the transonic wind tunnel (HST) of the National Aerospace Laboratory (NLR). This wind tunnel consists of a closed circuit with a test section of 1.60 x 2.00 m^2. Top and bottom of the test section are slotted walls with an open ratio of 12 percent. The velocity range of this tunnel is $0 \leq Ma \leq 1.25$ and by changing the stagnation pressure from $P_0 = 12.5$ kPa to $P_0 = 400$ kPa a wide range of Reynolds numbers can be covered. For further details the reader is referred to Reference 4.

3 TEST PROCEDURES

3.1 Pressure measurements

The measurement of the mean steady and unsteady pressures on the model was performed with the help of pressure tubes, connecting the pressure orifices in the wing surface with scanning valves outside the model. The electrical signals from the transducers in the scanning valves were measured and then reduced to the actual aerodynamic quantities at the model surface (for definitions, see Appendix).

In the steady case, this reduction is a straight-forward procedure. However, in the unsteady case the measured pressures had to be corrected for the dynamic response characteristics of the pressure tubes.

As described in detail in Reference 5, the transfer of oscillatory pressures through pressure tubes depends on the dimensions of the tubing system, the frequency of oscillation, the mean steady pressure and the velocity of the main flow across the tube entrance. For the present wing model with control surface the dimensions of each tube in the wing as well as in the control surface were considered to be identical. This implied the existence of a common transfer function for all tubes in the wing and another transfer function for all tubes in the control surface. For a certain oscillation frequency the two transfer functions depended only on the local mean steady pressure and the flow velocity across the tube entrance. For a given stagnation pressure of the wind-tunnel, the latter two parameters are directly related and thus can be replaced by one. In practice the mean steady pressure proved to be the most suitable parameter, since this quantity was measured simultaneously with the unsteady pressures at the orifices. In principle, the transfer function can be obtained both theoretically and experimentally. In the present experiment the calibration of transfer functions was performed experimentally during the tests. For that purpose seven miniature pressure transducers were installed into the wing at section 2, very close to the entrance of each pressure tube. The same was done with five transducers in the control surface (see Figure 3). This section was chosen because it was considered to cover the full range of possible mean steady entrance pressures. The pressures measured by the transducers could be regarded as the input to the corresponding pressure tubes and so a calibration of the transfer functions during the tests was obtained. By collecting the data for these tubes and by plotting them as a function of the mean steady pressure (or the local Mach number), the required calibration curves (Figure 5) were obtained. The curves have been plotted as the real and imaginary part of the complex ratio PU/PI, in which PU is the unsteady pressure measured in the scanivalve and PI is the unsteady pressure at the model surface as measured by the corresponding miniature pressure transducers. The data reduction for all the tubes has been indicated schematically in Figure 6.

The vector PI, denoting the unsteady pressures at the model surface, is obtained from the vector PU (being the unsteady pressure measured in the scanning valve) by a counterclockwise rotation ϕ and a reduction in magnitude with a factor α. Next, the vector PI is decomposed in a component in phase (real part) and a component in quadrature (imaginary part) with respect to the motion of the model. Unfortunately, during the tests the pressure orifices at 3 per cent in sections 3 and 5 on the upper surface were choked. In the unsteady measurements therefore the pressure coefficients for these two orifices were substituted by the mean value of the pressure coefficients at 3 per cent in sections 2 and 4, and 4 and 6 respectively. From the five in-situ transducers in section 2 in the control surface the one at 82 per cent was out of order during the tests.

3.2 Vibration modes

The vibration modes of the wing were monitored by six accelerometers (nos. 3 to 8, in Figure 3), while two accelerometers (nos. 1 and 2 in Figure 3) measured the amplitude of the control surface rotation. Two displacement transducers (nos. 9 and 10) measured the mean deflection and amplitude of rotation of the hinge axis just outside the tunnel wall.

In the tabulated results (Part II) the unsteady displacements of the accelerometers and the displacement transducers have been normalized by the unsteady displacement of accelerometer no. 1, while the amplitude of rotation in stream-wise direction of the control surface expressed in degrees, is given for the section of accelerometer no. 1. The normalized values of the displacement transducers nos. 9 and 10 were calculated as if they had the same distance from the hinge axis as accelerometer no. 1.

During the tests neither control surface nor wing appeared to be completely rigid. Due to friction in the bearings and a finite torsional stiffness of the control surface the amplitude of rotation measured by accelerometer no. 2 was 10 to 15 per cent less than the amplitude measured by accelerometer no. 1. Further, a consequence of the low bending stiffness of the wing outer part, the vibration mode depended on the unsteady airloads on that part. This is especially the case at transonic conditions. After the tests had been terminated it was found that in the last test runs accelerometers nos. 3 and 4 had failed. So the values of the normalized displacements of accelerometers nos. 3 and 4 are meaningless for test runs nos. 194 and higher.

4 MEASURING EQUIPMENT AND DATA REDUCTION

The wind-tunnel tests were performed by means of a processor ("PHAROS") designed for unsteady measurements (Reference 6). This computer-controlled device, performs a series of tasks. It controls the model excitation through a two-phase oscillator with variable frequency. It accepts simultaneously 48 measuring signals, which then are fed into conditioners and transfer function analyzers to obtain the steady component and the real and imaginary part of the harmonic components. In this way the time required for one test point is reduced to less than two minutes. Further it stores the data and performs a quick-look analysis with pre-determined transfer functions for the tubing system. A block-diagram of the equipment is presented in Figure 7, while a picture of it is given in Figure 8.

The final data reduction took place with the procedures described in section 3.1.

As a result, the following quantities were obtained (for definitions, see Appendix).

- the chordwise distribution of the (mean) steady pressure coefficient CP;
- the chordwise distribution of the quasi-steady pressure coefficient CPI, obtained from three steady measurements, namely (i) a run with zero mean flap deflection (δ_0), (ii) a run with a mean flap deflection of + 0.5 degrees ($\delta_0 + \delta_1$) and (iii) a run with a flap deflection of -0.5 degrees ($\delta_0 + \delta_2$). The other test conditions were kept the same.
- the chordwise distribution of the unsteady pressure coefficient CPI, normalized with respect to the angular displacement of the control surface in the section of accelerometer 1;
- sectional steady, quasi-steady and unsteady lift and moment coefficients obtained by integration of the pressure distributions;
- total steady, quasi-steady and unsteady lift coefficients for the wing obtained by integration in spanwise direction of the sectional coefficients;
- total steady, quasi-steady and unsteady lift and hinge moment coefficients

for the control surface obtained by integration in spanwise direction of the sectional coefficients; and

- vibration modes of the wing and the control surface.

5 TEST PROGRAM

The tests on the wing with the inboard control surface covered the Mach number range between Ma = 0.6 and Ma = 1.25; the frequencies of oscillation were 20 and 40 Hz. The maximum values of the reduced frequency achieved during the tests varied from K = 0.4 at Ma = 0.6 to K = 0.215 at Ma = 1.25. The tests were performed at mean incidences of ALPHA = 0.0 and 1.5 degrees and with amplitudes of control surface oscillation AMPL. = 0.5 degrees at a mean deflection DELTA = about 0.

To determine the unsteady airloads for zero frequency ("quasi-steady" results), a series of steady measurements was carried out at control surface deflections DELTA = -0.5, 0.0 and + 0.5 degrees, respectively.

At summary of the test program for the wing with inboard control surface is shown in Table 1.

6 FINAL REMARK

In this report only a description has been given of the general test set-up and test procedures of the wind-tunnel tests on a wing equipped with an oscillating inboard control surface. Its already mentioned in section 1 the tabulated results will be presented in a subsequent Part II of this report.

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APPENDIX

Definitions of steady, quasi-steady and unsteady aerodynamic quantities for wing and control surface

A.1 Wing

A.1.1 Steady

Pressure coefficient:

$$CP = (P_{loc} - P)/Q$$

Sectional normal force:

$$Z = CZ.Q.C \ , \ CZ = -\int_o^1 (CP_u - CP_\ell).d(x/C)$$

Sectional pitching moment about quarter-chord point (positive nose down):

$$M = CM.Q.C^2 \ , \ CM = -\int_o^1 (CP_u - CP_\ell).(x/C - 0.25).d(x/C)$$

Total wing normal force:

$$Z_{wing} = CZ_{wing}.Q.\bar{C}.S \ , \ CZ_{wing} = \int_o^1 (CZ.C)/\bar{C}.d(y/S)$$

A.1.2 Quasi-steady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM$$

$$CPIRE = \frac{CP_{(\delta_o + \delta_1)} - CP_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CP/\Delta\delta \quad ;$$

$$CPIIM = 0.0$$

Sectional normal force:

$$ZI = Q.C.CZI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CZI = CZIRE + i.CZIIM$$

$$CZIRE = \frac{CZ_{(\delta_o + \delta_1)} - CZ_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CZ/\Delta\delta \ ; \ CZIIM = 0.0$$

Sectional pitching moment (positive nose down):

$$MI = Q.C^2.CMI.\Delta\delta.e^{i\omega t} \ ,$$

$$CMI = CMIRE + i.CMIIM$$

$$CMIRE = \frac{CM_{(\delta_o + \delta_1)} - CM_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CM/\Delta\delta \ ; \ CMIIM = 0.0$$

Total wing normal force:

$$ZI_{wing} = Q.\bar{C}.S.CZI_{wing}.\Delta\delta.e^{i\omega t} \ ,$$

$$CZI_{wing} = CZIRE_{wing} + i.CZIIM_{wing}$$

$$CZIRE_{wing} = \int_o^1 (CZIRE.C)/\bar{C}.d(y/S) \ ; \ CZIIM = 0.0$$

A.1.3 Unsteady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM = PI/(Q.\Delta\delta)$$

Sectional normal force:

$$ZI = Q.C.CZI.\Delta\delta.e^{i\omega t} \ ,$$

$$CZI = CZIRE + i.CZIIM = - \int_o^1 (CPI_u - CPI_\ell).d(x/C)$$

Sectional pitching moment (positive nose down):

$$MI = Q.C^2.CMI.\Delta\delta.e^{i\omega t} \ ,$$

$$CMI = CMIRE + i.CMIIM = - \int_o^1 (CPI_u - CPI_\ell).(x/C - 0.25).d(x/C)$$

Total wing normal force:

$$ZI_{wing} = Q.\bar{C}.S.CZI_{wing}.\Delta\delta.e^{i\omega t}$$

$$CZI_{wing} = CZIRE_{wing} + i.CZIIM_{wing} = \int_o^1 (CZI.C)/\bar{C}.d(y/S)$$

A.2 Control surface

A.2.1 Steady

Pressure coefficient:

$$CP = (P_{loc} - P)/Q$$

Sectional normal force:

$$R = CR.Q.C \ , \ CR = -\int_{0.82}^{1} (CP_u - CP_\ell).d(x/C)$$

Sectional hinge moment:

$$N = CN.Q.C^2 \ , \ CN = -\int_{0.82}^{1} (CP_u - CP_\ell).(x/C - 0.82).d(x/C)$$

Total normal force:

$$R_{control} = CR_{control}.Q.\bar{C}.S \ , \ CR_{control} = \int_{0}^{0.5864} (CR.C)/\bar{C}.d(y/S)$$

Total hinge moment (positive control surface up):

$$N_{control} = CN_{control}.Q.\bar{C}^2.S \ , \ CN_{control} = \int_{0}^{0.5864} (CN.C^2)/\bar{C}^2.d(y/S)$$

A.2.2 Quasi-steady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM$$

$$CPIRE = \frac{CP_{(\delta_0 + \delta_1)} - CP_{(\delta_0 + \delta_2)}}{\delta_1 - \delta_2} = \Delta CP/\Delta\delta \ ;$$

$$CPIIM = 0.0$$

Sectional normal force:

$$RI = Q.C.CRI.\Delta\delta.e^{i\omega t} \ ,$$

$$CRI = CRIRE + i.CRIIM$$

$$CRIRE = \frac{CR_{(\delta_0 + \delta_1)} - CR_{(\delta_0 + \delta_2)}}{\delta_1 - \delta_2} = \Delta CR/\Delta\delta \ ; \ CRIIM = 0.0$$

Sectional hinge moment (positive control surface up):

$$NI = Q.C^2.CNI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI = CNIRE + i.CNIIM$$

$$CNIRE = \frac{CN_{(\delta_o + \delta_1)} - CN_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CN/\Delta\delta \ ; \ CNIIM = 0.0$$

Total normal force:

$$RI_{control} = Q.\bar{C}.S.CRI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI_{control} = CRIRE_{control} + i.CRIIM_{control}$$

$$CRIRE_{control} = \int_{o}^{0.5864} (CRIRE.C)/\bar{C}.d(y/S) \ ; \ CRIIM = 0.0$$

Total hinge moment (positive control surface up):

$$NI_{control} = Q.\bar{C}^2.S.CNI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI_{control} = CNIRE_{control} + i.CNIIM_{control}$$

$$CNIRE_{control} = \int_{o}^{0.5864} (CNIRE.C^2)/\bar{C}^2.d(y/S) \ ; \ CNIIM = 0.0$$

A.2.3 Unsteady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM = PI/(Q.\Delta\delta)$$

Sectional normal force:

$$RI = Q.C.CRI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI = CRIRE + i.CRIIM = - \int_{0.82}^{1} (CPI_u - CPI_\ell).d(x/C)$$

Sectional hinge moment (positive control surface up):

$$NI = Q.C^2.CNI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI = CNIRE + i.CNIIM = - \int_{0.82}^{1} (CPI_u - CPI_\ell).(x/C - 0.82).d(x/C)$$

Total normal force:

$$RI_{control} = Q.\bar{C}.S.CRI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI_{control} = CRIRE_{control} + i.CRIIM_{control} = \int_{0}^{0.5864} (CRI.C)/\bar{C}.d(y/S)$$

Total hinge moment (positive control surface up):

$$NI_{control} = Q.\bar{C}^2.S.CNI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI_{control} = CNIRE_{control} + i.CNIIM = \int_{0}^{0.5864} (CNI.C^2)/\bar{C}^2.d(y/S)$$

TABLE 1

TESTPROGRAM
STEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
(ALPHA = 0.0 degrees)

RUN no.	P0 nom. (kPa)	MACH	DELTA (degr.)	TABLE no.	REMARKS
10	100	.600	.488	2	
11	100	.600	-.505	3	
12	100	.600	.002	4	
101	100	.801	.486	5	
103	100	.800	-.499	6	
102	100	.800	-.003	7	
31	100	.899	.494	8	
32	100	.899	-.496	9	
33	100	.899	.002	10	
36	100	.923	.495	11	
37	100	.924	-.497	12	
38	100	.925	-.003	13	
42	100	.949	-.506	14	*
43	100	.949	.006	15	
46	100	1.000	.484	16	
47	100	.999	-.501	17	
48	100	.999	.003	18	
51	100	1.046	.492	19	
52	100	1.046	-.500	20	
53	100	1.046	.009	21	
56	100	1.096	.482	22	
57	100	1.096	-.505	23	
58	100	1.096	.000	24	
87	70	1.049	.493	25	
88	70	1.057	-.495	26	
89	70	1.050	.002	27	
72	70	1.096	.492	28	
73	70	1.094	-.505	29	
74	70	1.095	.000	30	
67	70	1.192	.489	31	
68	70	1.191	-.498	32	
69	70	1.193	-.005	33	
79	70	1.242	.491	34	
80	70	1.244	-.499	35	
81	70	1.244	-.001	36	

* run with DELTA =+.5 degrees is missing.

TABLE 2

TESTPROGRAM
STEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
(ALPHA = 1.5 degrees)

RUN no.	P0 nom. (kPa)	MACH	DELTA (degr.)	TABLE no.
121	100	.604	.497	37
122	100	.601	-.499	38
123	100	.599	-.004	39
156	100	.800	.499	40
157	100	.801	-.501	41
158	100	.801	-.001	42
162	100	.850	.501	43
163	100	.849	-.501	44
164	100	.849	-.002	45
167	100	.876	.501	46
168	100	.876	-.502	47
169	100	.877	.002	48
173	100	.901	.496	49
178	100	.900	-.501	50
175	100	.900	-.003	51
179	100	.926	.502	52
181	100	.923	-.503	53
182	100	.927	-.002	54
185	100	.950	.503	55
186	100	.950	-.502	56
187	100	.950	-.002	57
190	100	1.000	.497	58
191	100	.998	-.503	59
192	100	1.000	-.003	60
195	100	1.048	.497	61
196	100	1.048	-.499	62
197	100	1.049	-.004	63
200	100	1.097	.498	64
201	100	1.098	-.503	65
202	100	1.099	.003	66
230	70	1.048	.500	67
231	70	1.048	-.503	68
232	70	1.050	-.007	69
225	70	1.094	.499	70
226	70	1.096	-.501	71
227	70	1.094	-.001	72
220	70	1.194	.498	73
221	70	1.201	-.501	74
222	70	1.197	.001	75
215	70	1.235	.501	76
216	70	1.233	-.505	77
217	70	1.231	.000	78

TABLE 3

TESTPROGRAM
UNSTEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
(ALPHA = 0.0 degrees)

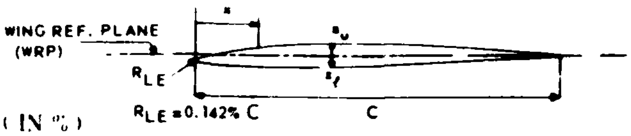
RUN no.	PO nom. (kPa)	MACH	DELTA (degr.)	AMPL. (degr.)	FREQ. (Hz)	RED.FR.	TABLE no.
12	100	.600	.002	.496	0	.000	79
109	100	.599	-.001	.491	20	.202	80
111	100	.599	-.004	.527	40	.404	81
102	100	.800	-.003	.492	0	.000	82
105	100	.800	-.009	.487	20	.155	83
108	100	.800	-.008	.505	40	.310	84
33	100	.899	.002	.495	0	.000	85
97	100	.901	-.001	.471	20	.139	86
100	100	.900	.000	.503	40	.279	87
38	100	.925	-.003	.496	0	.000	88
112	100	.925	-.001	.475	20	.137	89
114	100	.925	-.003	.524	40	.273	90
43	100	.949	.006	.256	0	.000	91
115	100	.951	-.007	.474	20	.133	92
116	100	.950	-.001	.498	40	.266	93
48	100	.999	.003	.492	0	.000	94
49	100	1.001	.003	.452	20	.128	95
50	100	1.000	.013	.473	40	.255	96
53	100	1.046	.009	.497	0	.000	97
54	100	1.046	-.004	.444	20	.123	98
55	100	1.047	.003	.466	40	.245	99
58	100	1.096	.000	.494	0	.000	100
59	100	1.096	-.007	.450	20	.118	101
60	100	1.095	.000	.447	40	.236	102
89	70	1.050	.002	.494	0	.000	103
91	70	1.050	-.003	.457	20	.122	104
92	70	1.048	-.002	.474	40	.245	105
74	70	1.095	.000	.478	0	.000	106
75	70	1.095	-.005	.453	20	.118	107
76	70	1.096	-.001	.474	40	.235	108
69	70	1.193	-.005	.494	0	.000	109
70	70	1.193	.001	.462	20	.110	110
71	70	1.193	.015	.486	40	.220	111
81	70	1.244	-.001	.495	0	.000	112
83	70	1.244	-.001	.452	20	.107	113
86	70	1.244	-.003	.470	40	.213	114

TABLE 4

TESTPROGRAM
UNSTEADY PRESSURE MEASUREMENTS ON NF-5 WING WITH INBOARD CONTROL SURFACE.
(ALPHA = 1.5 degrees)

RUN no.	P0 nom. (kPa)	MACH	DELTA (degr.)	AMPL. (degr.)	FREQ. (Hz)	RED.FR.	TABLE no.	REMARKS
123	100	.599	-.004	.498	0	.000	115	
154	100	.600	.002	.491	20	.204	116	
155	100	.600	.010	.513	40	.407	117	
158	100	.801	-.001	.500	0	.000	118	
161	100	.800	-.002	.477	20	.156	119	
160	100	.800	-.005	.441	40	.213	120	
164	100	.849	-.002	.501	0	.000	121	
165	100	.849	-.003	.457	20	.148	122	
166	100	.849	-.004	.492	40	.295	123	
169	100	.877	.002	.502	0	.000	124	
170	100	.874	-.001	.477	20	.144	125	
172	100	.874	.012	.430	40	.287	126	
175	100	.900	-.003	.499	0	.000	127	
176	100	.900	-.005	.501	20	.140	128	
177	100	.900	.000	.490	40	.279	129	
182	100	.927	-.002	.503	0	.000	130	
183	100	.926	-.004	.497	20	.136	131	
184	100	.925	.008	.484	40	.273	132	
187	100	.950	-.002	.503	0	.000	133	
188	100	.950	-.004	.481	20	.133	134	
189	100	.950	-.003	.491	40	.266	135	
192	100	1.000	-.003	.500	0	.000	136	
193	100	1.000	-.007	.500	20	.127	137	
194	100	.997	-.004	.485	40	.255	138	**
197	100	1.049	-.004	.498	0	.000	139	
198	100	1.047	-.003	.466	20	.122	140	@
199	100	1.048	-.003	.458	40	.244	141	**
202	100	1.099	.003	.500	0	.000	142	
203	100	1.096	.000	.474	20	.117	143	@
204	100	1.098	-.003	.474	40	.234	144	@
232	70	1.050	-.007	.502	0	.000	145	
233	70	1.050	-.002	.481	20	.122	146	@
234	70	1.087	-.002	.498	40	.237	147	@
227	70	1.094	-.001	.500	0	.000	148	
228	70	1.098	-.002	.473	20	.115	149	@
229	70	1.098	.002	.500	40	.221	150	@
222	70	1.197	.001	.499	0	.000	151	
223	70	1.199	-.002	.477	20	.109	152	@
224	70	1.196	-.002	.498	40	.219	153	@
217	70	1.231	.000	.503	0	.000	154	
218	70	1.233	-.003	.458	20	.108	155	@
219	70	1.233	-.004	.477	40	.215	156	@

** accelerometer 4 out of order.
@ accelerometer 3 and 4 out of order.



AIRFOIL CO-ORDINATES (IN %)

x/C	z_u/C	z_l/C
0	[illegible]	[illegible]
0.1	[illegible]	[illegible]
0.2	[illegible]	[illegible]
0.3	[illegible]	[illegible]
0.4	[illegible]	[illegible]
0.5	[illegible]	[illegible]
0.6	[illegible]	[illegible]
0.7	[illegible]	[illegible]
0.8	[illegible]	[illegible]
0.9	[illegible]	[illegible]
1.0	[illegible]	[illegible]
1.25	[illegible]	[illegible]
1.50	[illegible]	[illegible]
1.75	[illegible]	[illegible]
2.00	[illegible]	[illegible]
2.25	[illegible]	[illegible]
2.50	[illegible]	[illegible]
3.00	[illegible]	[illegible]
4.00	[illegible]	[illegible]
5.00	[illegible]	[illegible]
6.00	[illegible]	[illegible]
7.00	[illegible]	[illegible]
8.00	[illegible]	[illegible]
9.00	[illegible]	[illegible]
10	[illegible]	[illegible]
11	[illegible]	[illegible]
12	[illegible]	[illegible]
13	[illegible]	[illegible]

x/C	z_u/C	z_l/C
14	[illegible]	[illegible]
15	[illegible]	[illegible]
16	[illegible]	[illegible]
17	[illegible]	[illegible]
18	[illegible]	[illegible]
19	[illegible]	[illegible]
20	[illegible]	[illegible]
21	[illegible]	[illegible]
22	[illegible]	[illegible]
23	[illegible]	[illegible]
24	[illegible]	[illegible]
25	[illegible]	[illegible]
26	[illegible]	[illegible]
27	[illegible]	[illegible]
28	[illegible]	[illegible]
29	[illegible]	[illegible]
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32	[illegible]	[illegible]
33	[illegible]	[illegible]
34	[illegible]	[illegible]
35	[illegible]	[illegible]
36	[illegible]	[illegible]
37	[illegible]	[illegible]
38	[illegible]	[illegible]
39	[illegible]	[illegible]
40	[illegible]	[illegible]

x/C	z_u/C(= z_l/C)
41	[illegible]
42	[illegible]
43	[illegible]
44	[illegible]
45	[illegible]
46	[illegible]
47	[illegible]
48	[illegible]
49	[illegible]
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64	[illegible]
65	[illegible]
66	[illegible]
67	[illegible]
68	[illegible]
69	[illegible]
70	[illegible]

x/C	z_u/C(= z_l/C)
71	[illegible]
72	[illegible]
73	[illegible]
74	[illegible]
75	[illegible]
76	[illegible]
77	1.44631
78	[illegible]
79	[illegible]
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81	[illegible]
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84	[illegible]
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87	[illegible]
88	[illegible]
89	[illegible]
90	[illegible]
91	[illegible]
92	[illegible]
93	[illegible]
94	[illegible]
95	[illegible]
96	[illegible]
97	[illegible]
98	[illegible]
99	[illegible]
100	0.04500

Co-ordinates of the airfoil of the wing

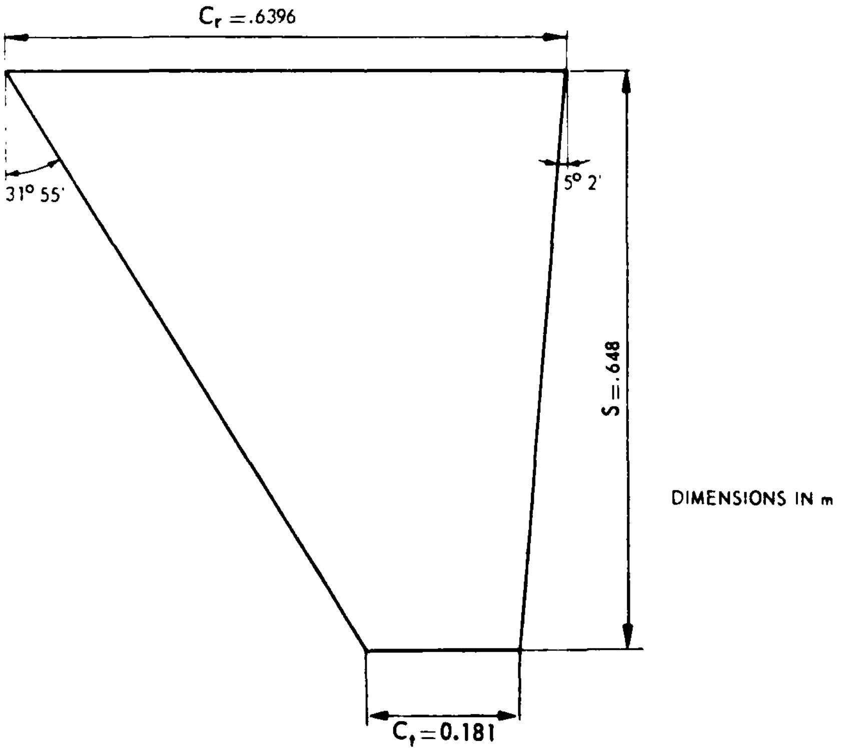

Figure 1 Dimensions of the Wing

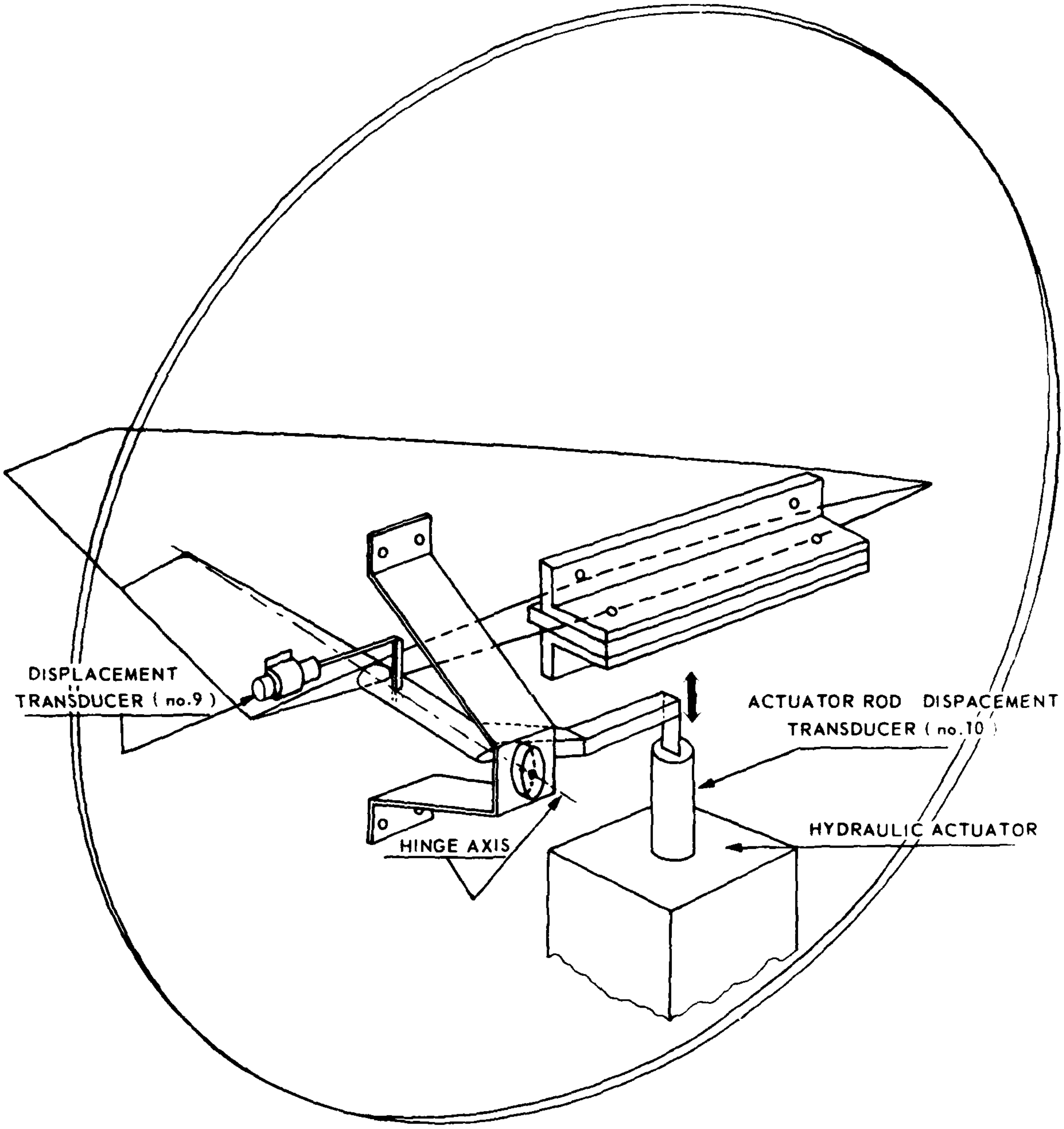

Figure 2 Schematic View of the Test Set-up

PRESSURE ORIFICES ON UPPER AND LOWER SURFACE				
WING SECTION	% SPAN	SECTIONS		
		1,2,3	3.5	4,5,6,7,8
1	17.4			
2	34.1	3		3
3	49.2	10		10
3.5	55.7	20		20
4	61.6	30		30
5	69.3	40		40
6	78.5	50		50
7	84.1	60		60
8	93.9	70		70
		80		80
		82	82	
		85.5	85.5	
		89	89	90
		92.5	92.5	
		96	96	

IN-SITU TRANSDUCERS IN WING SECTION 2 UPPER SURFACE ONLY	
% CHORD	
10	
20	
30	
40	
50	
60	
70	
82	(OUT OF ORDER)
85.5	
90	
92.5	
96	

ACCELEROMETERS IN WING PLANFORM		
NO.	X (m)	Y (m)
1	0.596	0.096
2	0.5745	0.291
3	0.2309	0.2971
4	0.518	0.252
5	0.3422	0.4772
6	0.5270	0.4772
7	0.4070	0.6176
8	0.5390	0.6176

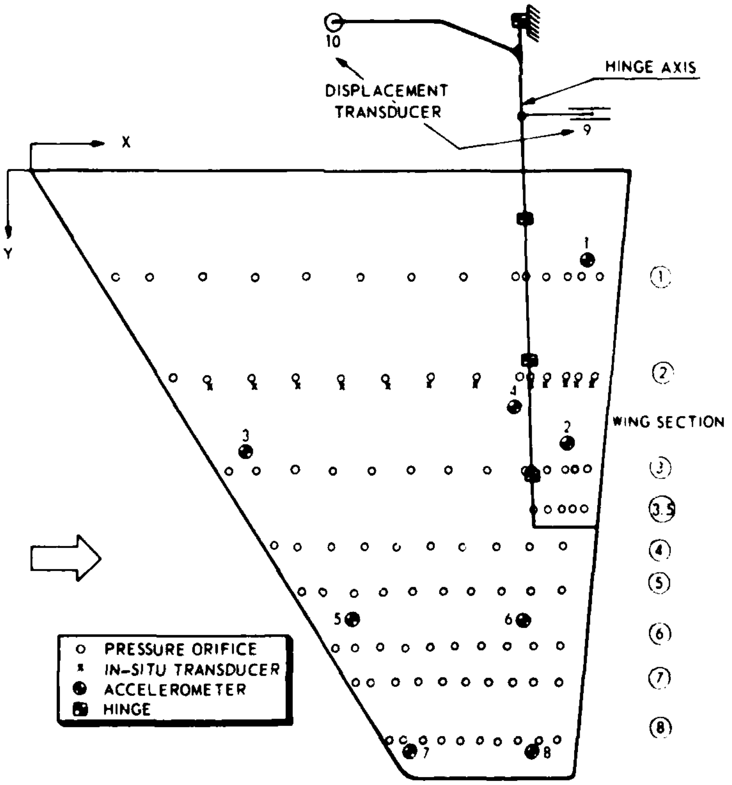

Figure 3 Location of Pressure Orifices, In-Situ Transducers and Accelerometers

Figure 4 Model in the Wind-Tunnel

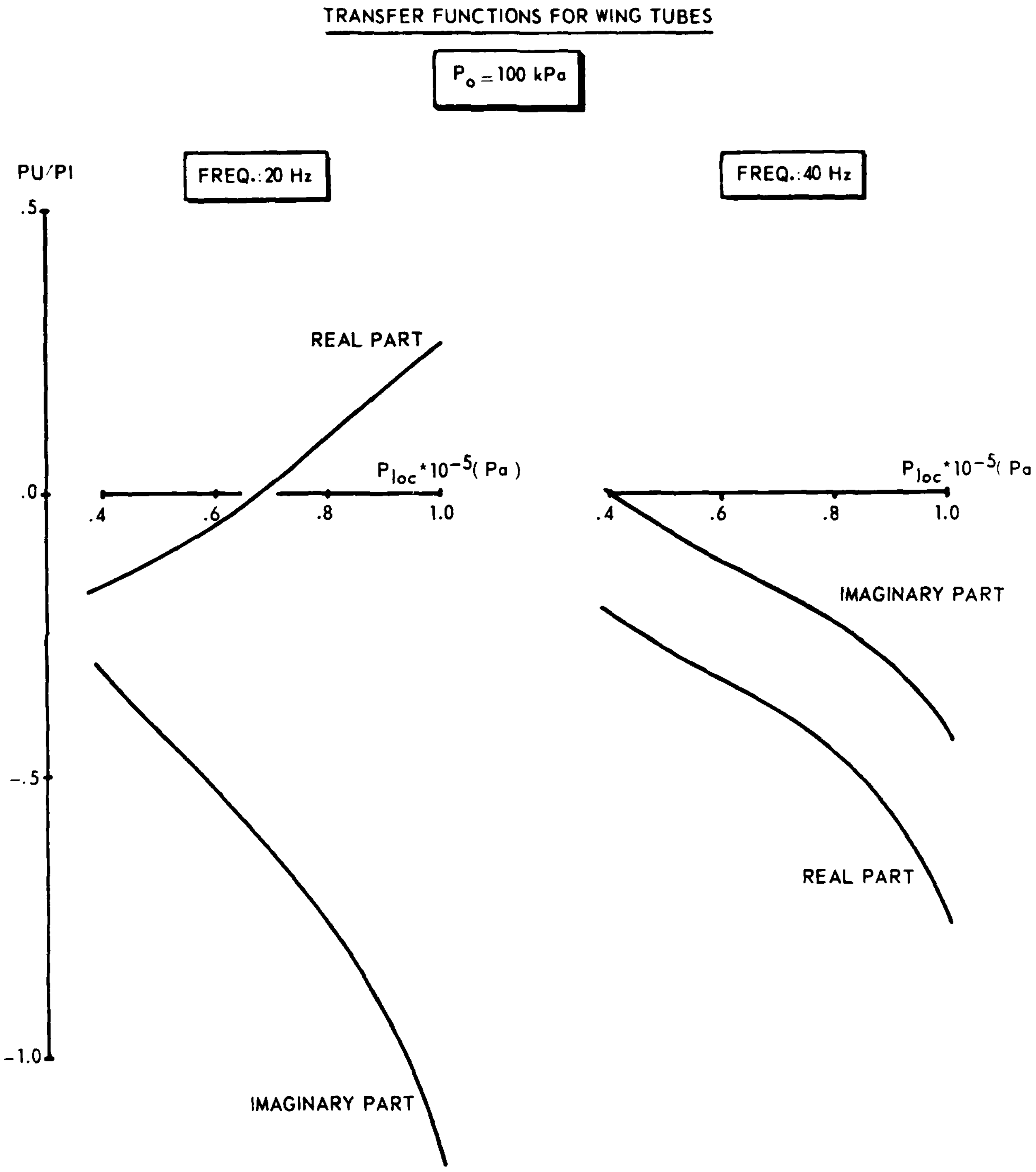

Figure 5a Transfer Functions Used for Data Reduction of the Unsteady Pressures

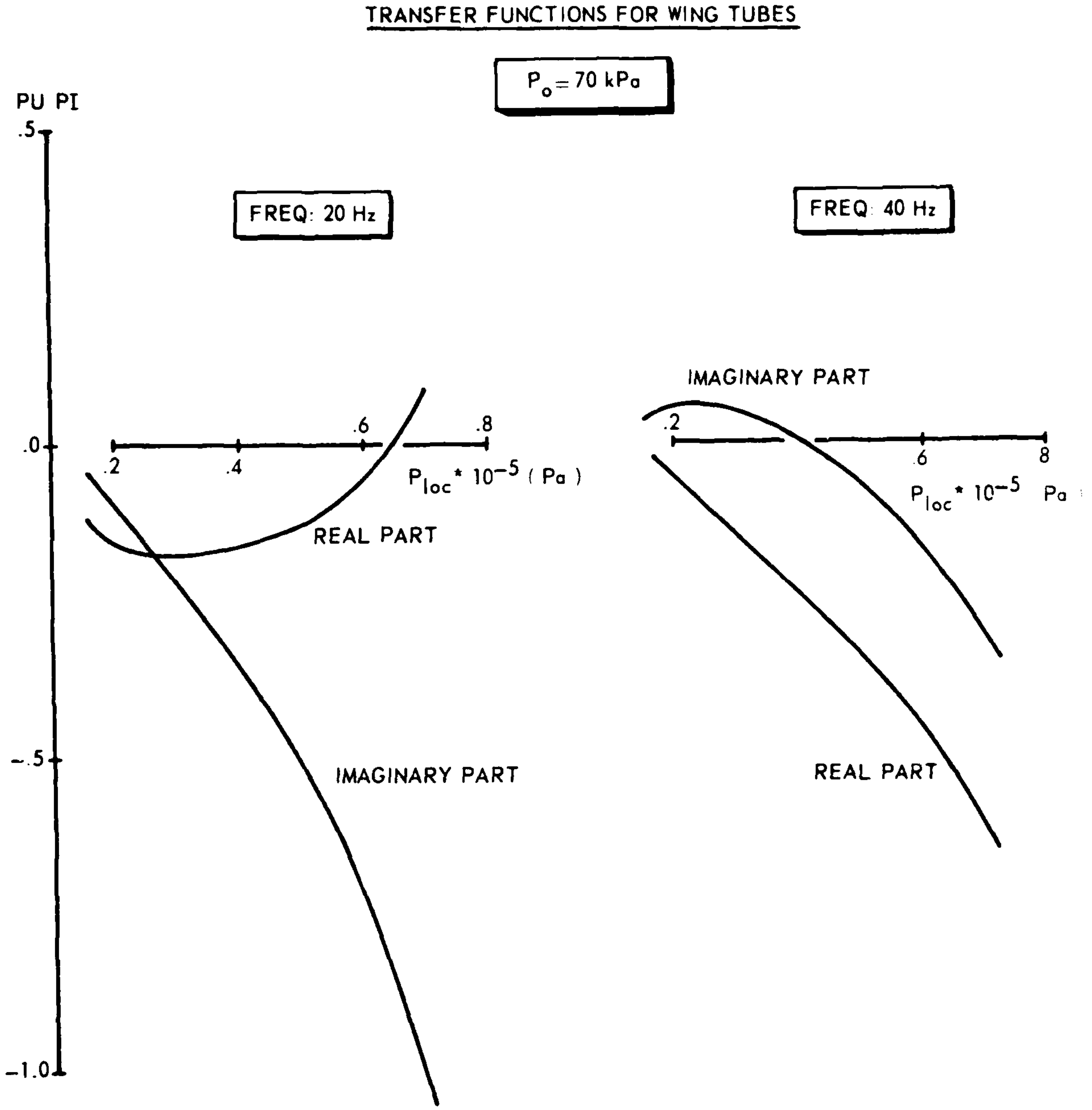

Figure 5b Transfer Functions Used for Data Reduction of the Unsteady Pressures

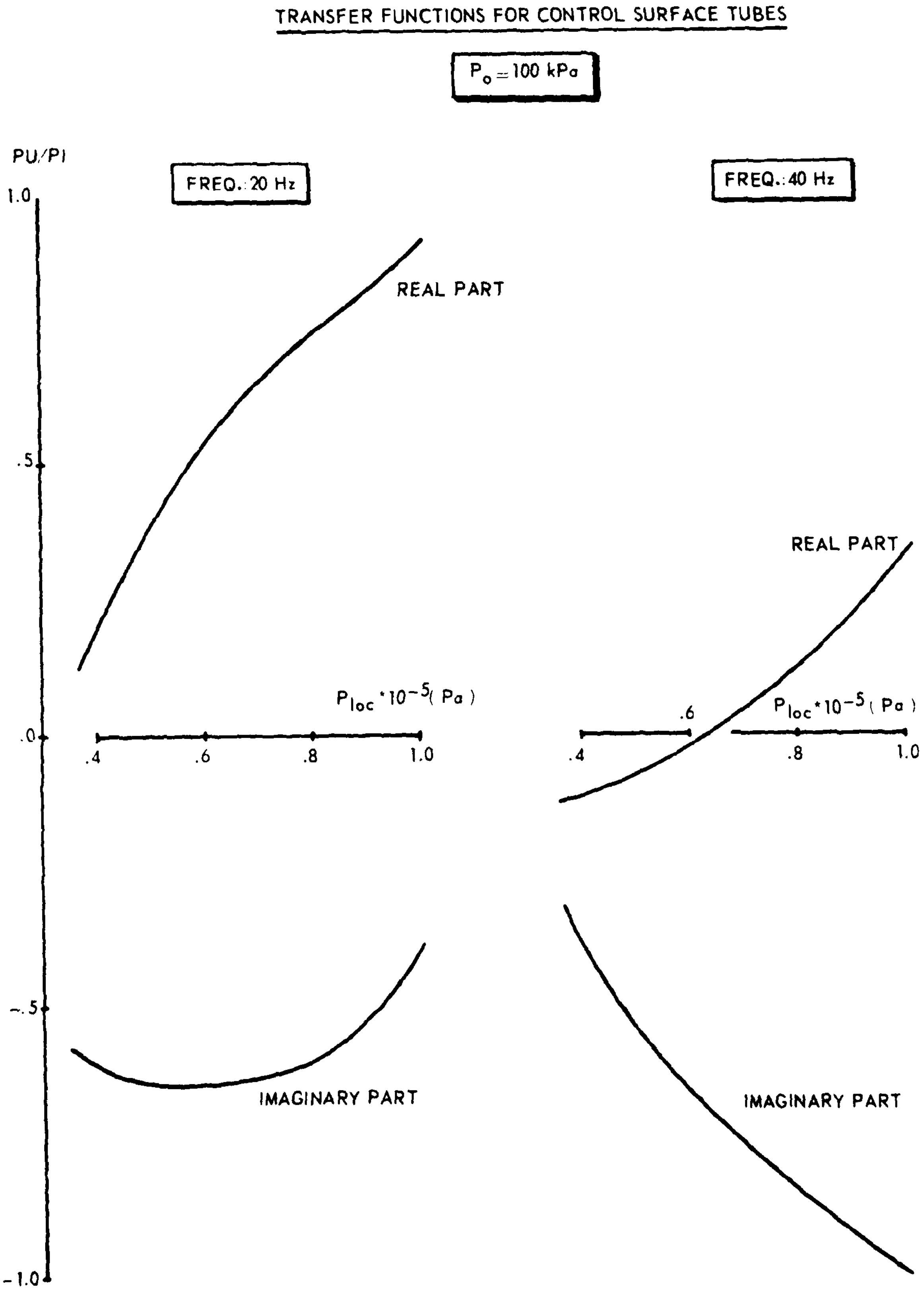

Figure 5c Transfer Functions Used for Data Reduction of the Unsteady Pressures (cont'd)

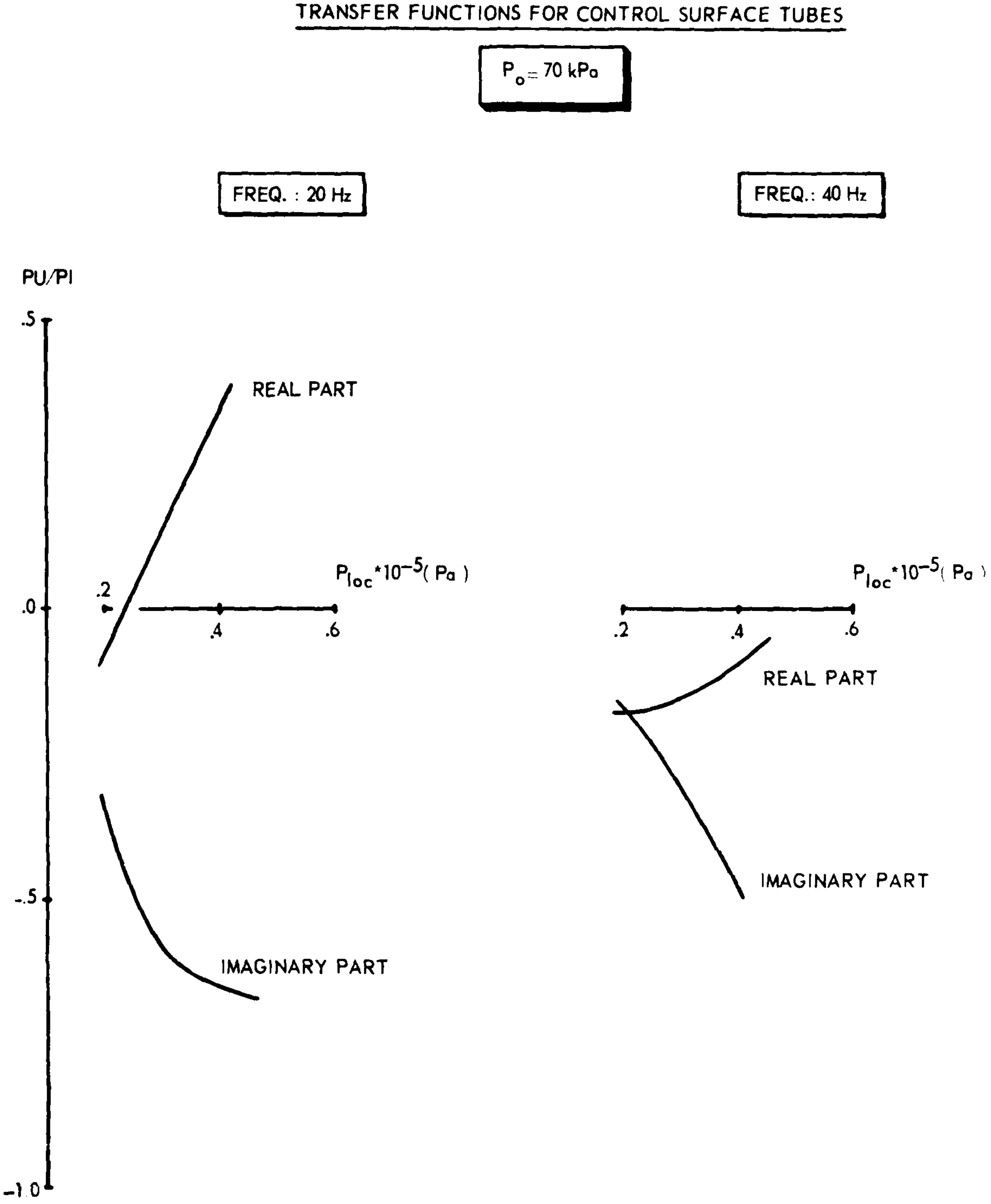

Figure 5d Transfer Functions Used for Data Reduction of the Unsteady Pressures (cont'd)

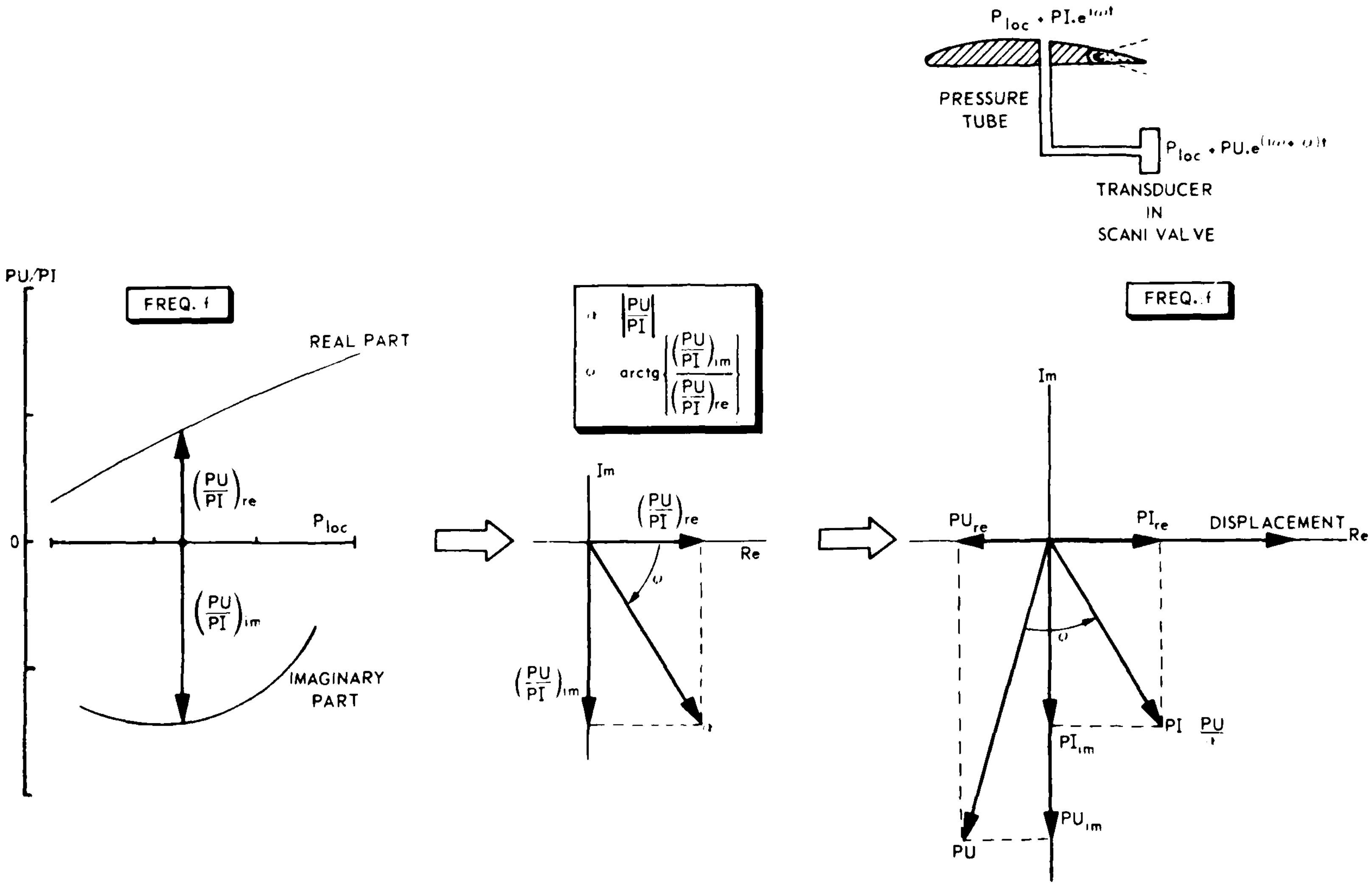

Figure 6 Principle of Unsteady Pressure Measuring Technique

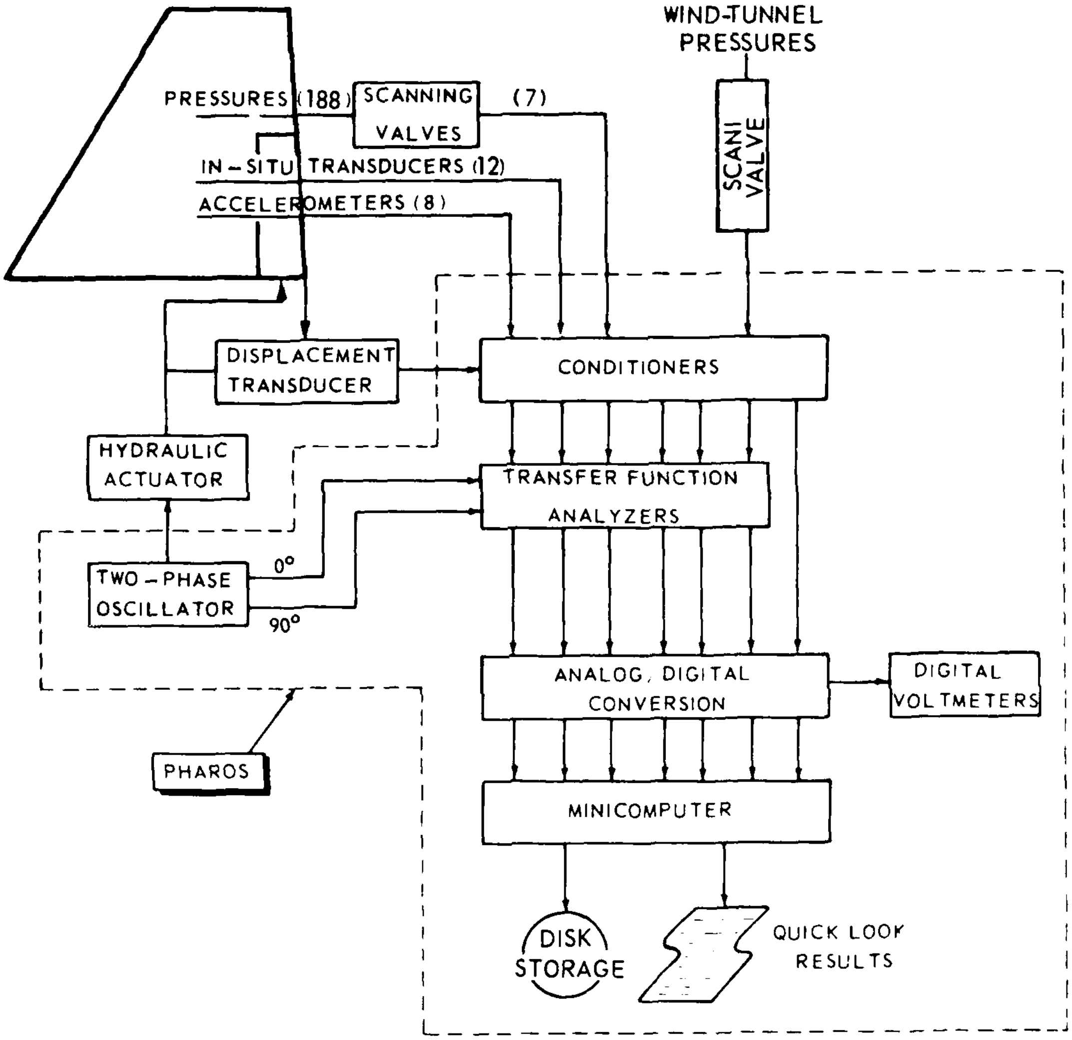

Figure 7 Block-Diagram of the Test Set-Up During Unsteady Measurements

Figure 8 Equipment for Unsteady Measurements PHAROS

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